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PART I

BOOK CONSTRUCTION



MORRIS, TASKER & CO.

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P. Munzinger, Engineer.



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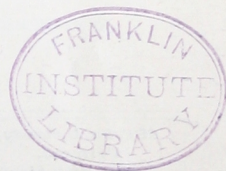




ROOF CONSTRUCTION.

The object of the present Paper is to ascertain, with mathematical certainty, the true strain on every part of an Iron Roof Frame; the proper manner of proportioning each part, and the best form of combination to secure the greatest economy with the needful safety. The writer includes the formulae of Rankin, Mosely, Van Knaven and Wiesbach.

P. Munzinger.



Load on Roof.—The load on a Roof is of two kinds: the permanent and the accidental load. The permanent load consists of—(a) the weight of the Roof Covering, of Slate, Tile or Metal, as the case may be, and its attachments, the weight of the frame-work.

The accidental load is the wind and snow pressure to which at times the Roof may be subjected.

We are in this country visited annually by gales of wind, their maximum forces amounting to from 20 to 25 lbs. per square foot, on a surface perpendicular to their direction.

The Normal Pressure for various inclinations of the Roof surface to the direction of the Wind.

Let the normal pressure = 40 lbs. per square foot.

Angle of Roof.	lbs. per square foot of surface.	Angle of Roof.	lbs. per square foot of surface.
5°	0.4	50°	29.2
10	1.7	60	34.0
20	6.2	70	38.5
30	13.2	80	39.8
40	21.4	90	40.0

Weight of Roof Covering per square foot.

Lead	6 to 8 lbs.
Zinc	1 to 1 $\frac{3}{4}$ "
Corrugated Iron	3 to 4 "
Slating	8 "
Pantiles	10 "
Tiles, (plain)	20 "
Slate with Iron Lath	10 "
Sheet Iron No. 16, W. G., and Lath	5 "
Corrugated Iron, and Lath	5 $\frac{1}{2}$ "
Cast Iron Plates $\frac{3}{8}$ inch thick	15 "
Sheet Iron No. 20 W. G. and Boarding	6 $\frac{1}{2}$ "

Snow Pressure from 2 to 2 $\frac{1}{2}$ lbs. per square foot must be added to each covering.

The weight of Truss is obtained after the strains are calculated.

THE following investigations are all based upon the supposition that the parts that receive and transmit the strains are free to act as the strains necessitate, being fastened only at their extremities with Pins or Bolts. When the diagonal Ties or Struts, are firmly connected together at their extremities by rivets or other similar fastenings, their normal actions are hampered. The symbol $\perp$ placed before a number which represents a strain, signifies that the strain is compressive; the symbol $=$ signifies that the strain is tensile.

We will now examine the effects produced by a load uniformly distributed upon a truss supported at both ends, using the following notations:

N = distance from centre to centre of Truss.

M = the number of square feet between two Trusses

w_1 = snow pressure per square foot.

w_2 = wind pressure per square foot of surface.

w_3 = weight of Truss and Covering per square foot.

w_4 = weight per square foot of its horizontal surface, including wind and snow pressures, weight of Truss and covering.

W = weight equally distributed throughout its entire span.

We can readily find the value of M .

$$M = N L_4$$

We will suppose the span = 100 feet, distance from centre to centre of Trusses to be 20 feet.

Here N = 20 feet.

$$M = 100 \times 20 = 2000 \text{ square feet.}$$

L_4 = 100 "

For the value w_4 and W .

$$w_4 = w_1 + w_2 + w_3.$$

$$W = w_4 M.$$

Assumed Weight and Dimensions.

Here, w_1 = 2.5 lbs for snow.

w_2 = 6.5 " pressure for wind.

w_3 = 15. " weight for Truss and covering.

M = 2000 square feet between two Trusses.

w_4 = 2.5 + 6.5 + 15. = 24 lbs per square foot of its horizontal plane.

$$W = 24 \times 2000 = 48000 \text{ lbs.}$$

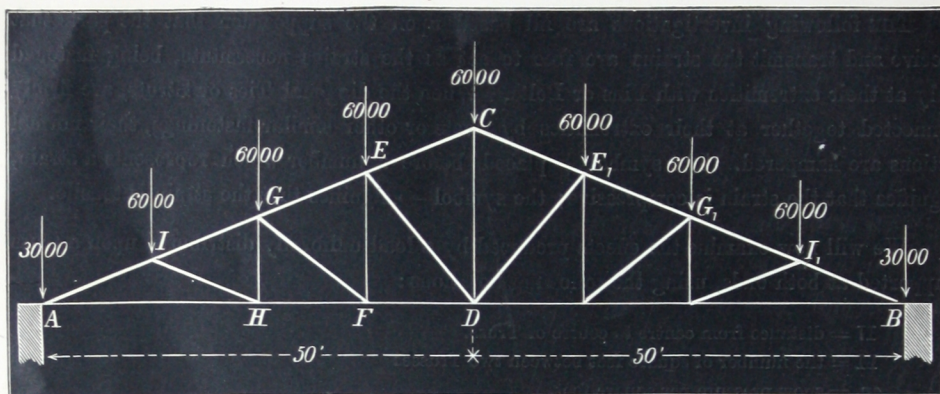
Here we have 48000 lbs. equally distributed over one Truss throughout its entire span, and the load per lineal unit.

$$w = \frac{W}{L_4}$$

Here W = 48000 lbs.

L_4 = 100 feet.

$$w = \frac{48000}{100} = 480 \text{ lbs. per lineal foot.}$$



Let the above figure represent a compound Truss, uniformly loaded with w per lineal unit; if S be the length of each apex, the Truss being loaded all over, each half of the Truss will carry half of the load; we will therefore consider the strain on one-half of the Truss.

Let S = the length of apex in feet.

w = the weight per lineal foot.

L_t = span the Truss in feet.

W = total weight on each apex.

n = number of apexes in Truss.

To Find the Weight of each Apex.

$$S = \frac{L_t}{n}$$

Here, $L_t = 100$ feet.

$n = 8$ apexes.

$$S = \frac{100}{8} = 12.5 \text{ feet.}$$

The Weight on each Apex.

$$W = S, w.$$

Here, $S = 12.5$ feet.

$w = 480$ lbs. per foot.

$$W = 12.5 \times 480 = 6000 \text{ lbs.}$$

In the above construction we have eight apexes, each carrying a load of 6000 lbs. which for the total weight of Truss equals 48000 lbs.

If we charge on each of the seven points, I, G, F, C, F, G, I, a weight of 6000 lbs., and at A, B, 3000 lbs. each, we can find the reactive force at the points of support.

We have the two moments about the point D, one caused by the weight between A and

D acting downwards, and the other depending upon the re-action of the wall **A** acting upwards; therefore the difference between these moments will be equal to the required moment.

The weight carried on one-half of the Truss equals 24000 lbs. minus 3000 lbs. carried by the wall. We have then for the re-active force on the supports,

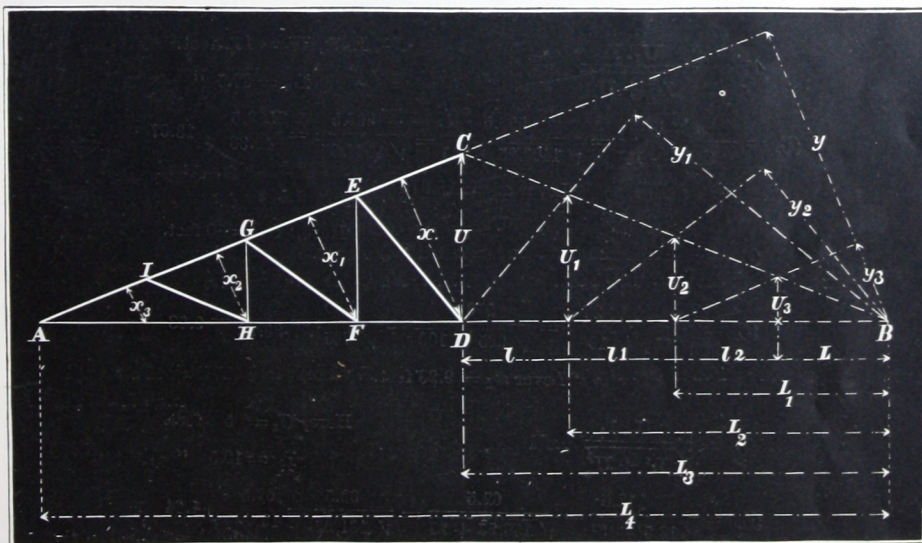
$$D = 24000 - 3000 \text{ or } D = 21,000.$$

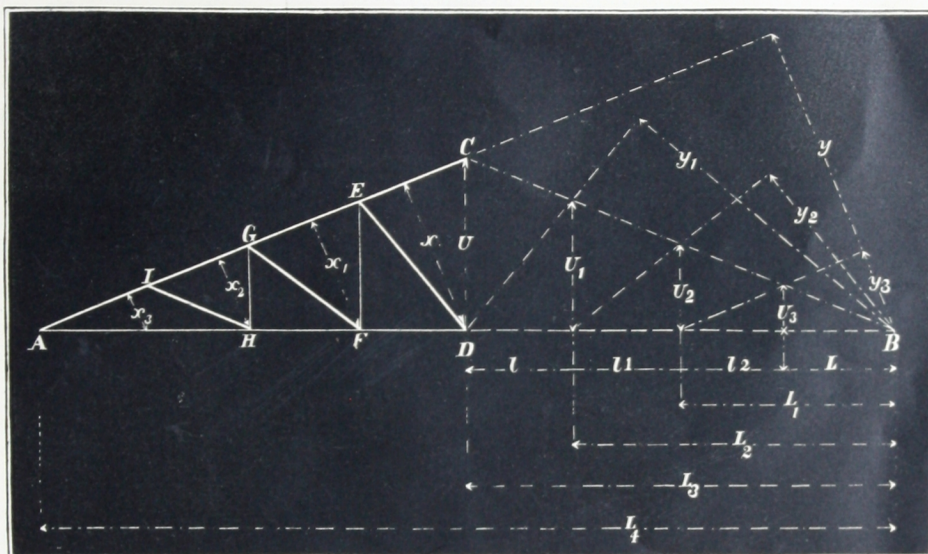
We have in all seven times 6000 lbs. acting downwards, and twice 21000 acting vertically upwards.

Before attempting to calculate the strains on the different parts of a Truss Roof, it is necessary first to calculate the length of Lever x and y , as shown in Diagram; it may be calculated by the following equation:

$$x = \frac{U L_3}{\sqrt{L_3^2 + U^2}} \quad x_1 = \frac{U L_2}{\sqrt{L_2^2 + U^2}} \quad x_2 = \frac{U L_1}{\sqrt{L_1^2 + U^2}} \quad x_3 = \frac{U L}{\sqrt{L^2 + U^2}}$$

$$y = \frac{L_4 U}{\sqrt{L_4^2 + U^2}} \quad y_1 = \frac{L_3 U}{\sqrt{L_3^2 + U^2}} \quad y_2 = \frac{L_2 U}{\sqrt{L_2^2 + U^2}} \quad y_3 = \frac{L_1 U}{\sqrt{L_1^2 + U^2}}$$





$$y = \frac{L_1 U}{\sqrt{L_2^2 + U^2}}$$

Here, $L_2 = 100$ feet.
 $L_1 = 50$ "
 $U = 50$ "

$$y = \frac{100 \times 20}{\sqrt{50^2 + 20^2}} = \frac{2000}{\sqrt{2500 + 400}} = \frac{2000}{\sqrt{2900}} = \frac{2000}{53.85} = 37.14$$

Lever $y = 37.14$ feet.

$$y_1 = \frac{L_3 U_1}{\sqrt{L_2^2 + U_1^2}}$$

Here, $L_3 = 50$ feet.
 $U_1 = 15$ "
 $L_2 = 12.5$ "

$$y_1 = \frac{50 \times 15}{\sqrt{12.5^2 + 15^2}} = \frac{750}{\sqrt{156.25 + 225}} = \frac{750}{\sqrt{381.25}} = \frac{750}{19.52} = 38.41$$

Lever $y_1 = 33.41$ feet.

$$y_2 = \frac{L_2 U_2}{\sqrt{L_1^2 + U_2^2}}$$

Here, $L_2 = 37.5$ feet.
 $U_2 = 15.0$ "
 $L_1 = 12.5$ "

$$y_2 = \frac{37.5 \times 10}{\sqrt{12.5^2 + 10^2}} = \frac{375}{\sqrt{156.25 + 100}} = \frac{375}{\sqrt{256.25}} = \frac{375}{16.08} = 23.32$$

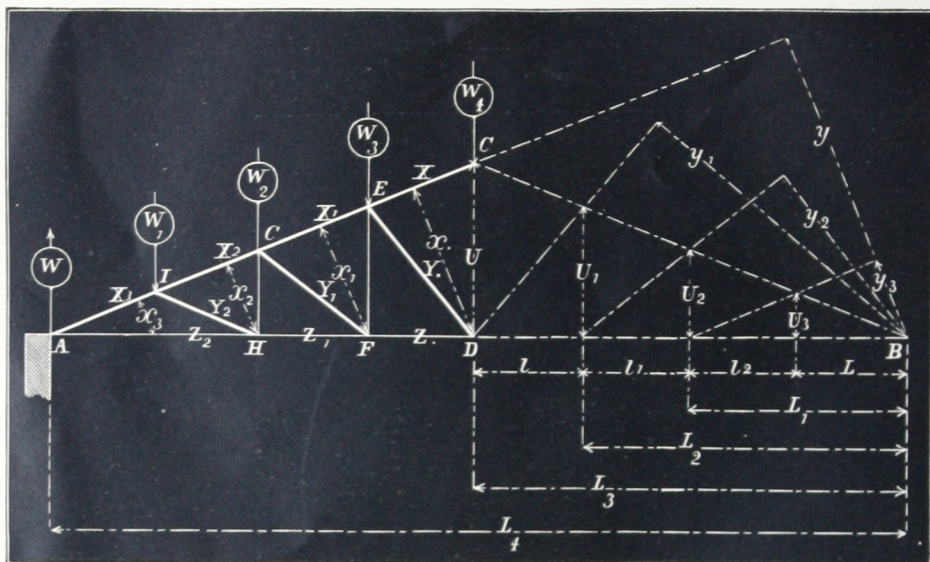
Lever $y_2 = 23.32$ feet.

$$y_3 = \frac{L_1 U_3}{\sqrt{L_2^2 + U_3^2}}$$

Here, $L_2 = 25.0$ feet.
 $U_3 = 5.0$ "
 $L_1 = 12.5$ "

$$y_3 = \frac{25 \times 5}{\sqrt{12.5^2 + 5^2}} = \frac{125}{\sqrt{156.25 + 25}} = \frac{125}{\sqrt{181.25}} = \frac{125}{13.46} = 9.28$$

Lever $y_3 = 9.28$ feet.



It is evident from what has previously been stated and exemplified, that if we wish to calculate the strains upon Roof Frames, we can use the following formulas and the above Diagram.

$$1. \quad X = \frac{W \cdot L_3 - [L_1 W_1 + L_2 W_2 + l \cdot W_3]}{x}$$

$$8. \quad Z_1 = \frac{W \cdot L_1 - (W_2 l_1)}{U_1}$$

$$2. \quad Y = \frac{W_1 l_1 + W_2 L_1 + W_3 L_1}{y}$$

$$9. \quad X_2 = \frac{W \cdot L_1 - [W_3 l_2]}{x_2}$$

$$3. \quad Z = \frac{W \cdot L_2 - (W_3 l_1 + W_1 L_1)}{U_1}$$

$$10. \quad Y_2 = \frac{W_1 l_2}{x_2}$$

$$4. \quad U_1 = \frac{W_2 l_1 + W_1 L_1}{L_2}$$

$$11. \quad Z_2 = \frac{W \cdot L}{U_2}$$

$$5. \quad X_1 = \frac{W \cdot L_2 - [W_2 l_1 + W_1 L_1]}{x_2}$$

$$12. \quad U_2 = \frac{W_1 l_2}{L_1}$$

$$6. \quad Y_1 = \frac{W_2 l_1 + W_1 L_1}{y_2}$$

$$13. \quad Z_3 = \frac{W \cdot L_2}{U_3}$$

$$7. \quad U_2 = \frac{W_3 L_1}{L_1}$$

$$14. \quad X_3 = \frac{W \cdot L_3}{x}$$

$$15. \quad U = \frac{X y - (W_4 L_3)}{L_3}$$

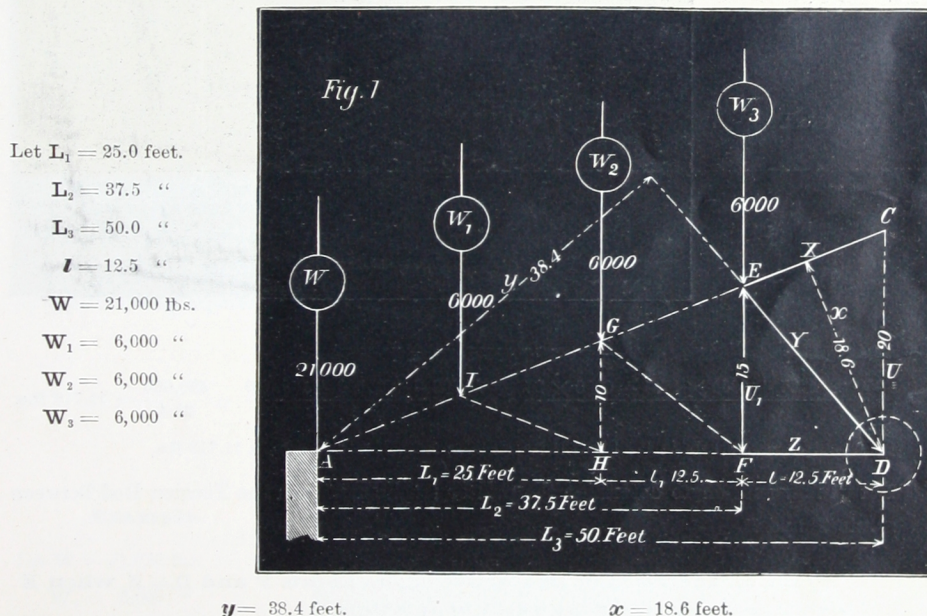
We will conclude this part of the subject with a practicable exemplification of the manner in which the strains are calculated.

As our object is merely to illustrate a principle, great accuracy will not be attempted and round numbers only will be used for length of the lever x and y .

The compressive strain produced on Rafter between the points **E** and **C = X**, if the section kept in equilibrium by the replaced forces **Y**, **X**, and **Z** may be regarded first as a lever with the fulcrum at the point **D**. If we consider the truss as half loaded it will be seen from the figure that we have 18000 lbs. acting downward and 21000 lbs. acting vertically upward.

Example.

Let Fig. 1 represent a Triangular Truss, described in which



The strains in the Rafters are obtained from Equation 1, page 8.

$$\mathbf{X} = \frac{\mathbf{W} \cdot \mathbf{L}_3 - [\mathbf{L}_1 \cdot \mathbf{W}_1 + \mathbf{L}_2 \cdot \mathbf{W}_2 + \mathbf{L} \cdot \mathbf{W}_3]}{x}$$

$$\mathbf{X} = \frac{21000 \times 50 - [25 \times 6000 + 37.5 \times 6000 + 12.5 \times 6000]}{18.6} =$$

$$\frac{1,050,000 - [150,000 + 225,000 + 75,000]}{18.6} = \frac{1,050,000 - 450,000}{18.6} = \frac{600,000}{18.6} = 32,258 \text{ lbs.}$$

We have for the strain **X** in Rafter between the points **E** and **C**, 32,258.



The Strut or compressive member forming the Rafter between the points **E** and **D = Y**, may conveniently be calculated with the Equation 2, page 8, if we take the point of rotation around **A** represented in Fig. 1.

Example.

Let $L_1 = 25.0$ feet.

$L_2 = 37.5$ "

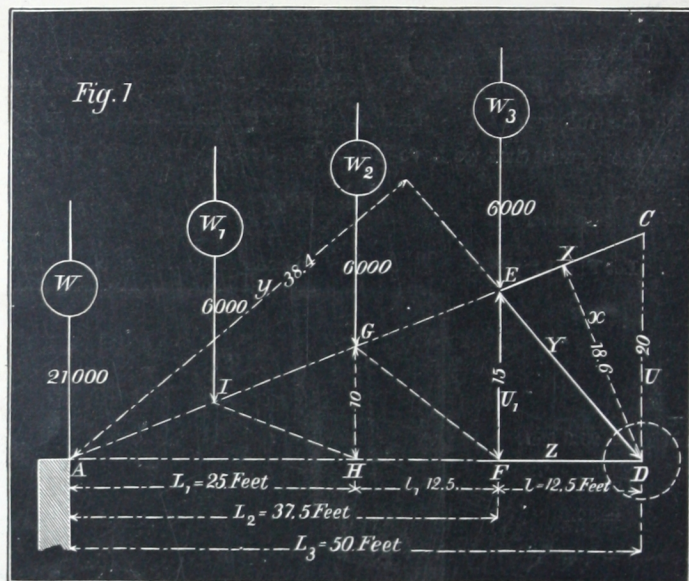
$l = 12.5$ "

$W_1 = 6000$ lbs.

$W_2 = 6000$ "

$W_3 = 6000$ "

$y = 38.4$ feet.



$$Y = \frac{W_3 l + W_2 L_2 + W_1 L_1}{y}$$

$$Y = \frac{6000 \times 12.5 + 6000 \times 37.5 + 6000 \times 25}{38.4} = \frac{75,000 + 225,000 + 150,000}{38.4} = \frac{450,000}{38.4} = 11,718 \text{ lbs.}$$

The compressive strain in the Strut between the points **E** and **D** equals 11,718 lbs.

Let us now pass on to determine the pull or tensile strain on the Tension Rod between the points **F** and **D**.

Tensile Strain on the Tension Rod between the points F and D = Z, when E is the point of rotation.

$$Z = \frac{W \cdot L_2 - (W_3 l + W_1 L_1)}{U_1}$$

Here $W = 21000$ lbs.

$W_1 = 6000$ lbs.

$L_2 = 37.5$ feet.

$L_1 = 25$ feet.

$U_1 = 15$ "

$$Z = \frac{21,000 \times 37.5 - (6,000 \times 12.5 + 6,000 \times 25)}{15} = \frac{7,875,000 - (75,000 + 150,000)}{15} =$$

$$\frac{375,000 - 260,000}{15} = \frac{562,500}{15} = 37,500 \text{ lbs.}$$

$$X_1 = \frac{21,000 \times 37.5 - [6,000 \times 12.5 + 6,000 \times 25]}{13.9} = \frac{787,500 - [75,000 + 150,000]}{13.9} =$$

$$\frac{787,500 - 225,000}{13.9} = \frac{562,500}{13.9} = 40,468 \text{ lbs.}$$

We have then for the strain in Rafter between the points G and E, 40,468 lbs.

Strain on the Strut between the points G and F = Y_1 when the rotation is around A.

Example.

$$Y_1 = \frac{W_2 L_1 + W_1 L_2}{y_2}$$

Let $W_2 = 6,000$ lbs.

$L_1 = 25.0$ feet.

$W_1 = 6,000$ "

$L_2 = 12.5$ "

$y_2 = 23.5$ feet.

$$Y_1 = \frac{6,000 \times 12.5 + 6,000 \times 25}{23.5} = \frac{225,000}{23.5} = 9,595 \text{ lbs.}$$

We have for strains in Strut 9,595 lbs.

Tensile Strain produced on the Queen-post between the points G and H = U_2 if we take the point of rotation around A, we use the following Equation.

$$U_2 = \frac{W_2 L_1}{L_2}$$

Let $W_2 = 6,000$ lbs.

$L_1 = 25.0$ feet.

$L_2 = 12.5$ "

$$U_2 = \frac{6,000 \times 25}{12.5} = \frac{75,000}{12.5} = 6,000 \text{ lbs.}$$

Tensile Strain on the Queen-post = 6,000 lbs.

Tensile Strain on the Tension-rod between the points H and F = Z_1 when the rotation is around G.

$$Z_1 = \frac{W \cdot L_1 - (W_2 L_2)}{U_2}$$

Let $W = 21,000$ lbs.

$L_1 = 25.0$ feet.

$W_2 = 6,000$ "

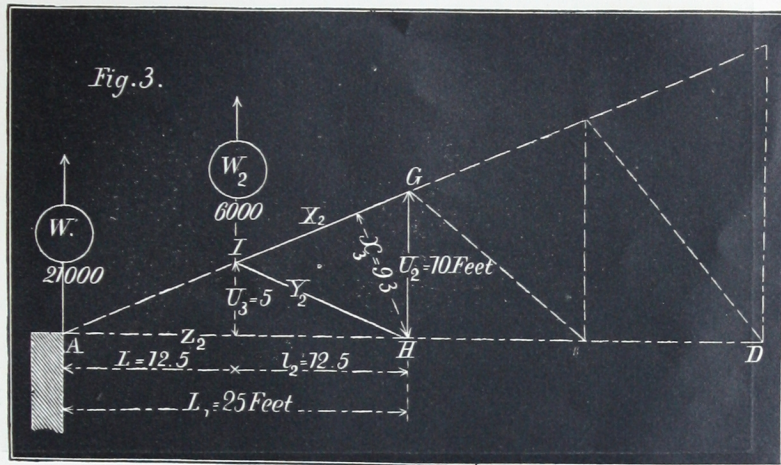
$L_2 = 12.5$ "

$U_2 = 6,000$ lbs.

$$Z_1 = \frac{21,000 \times 25 - (6,000 \times 12.5)}{6,000} = \frac{525,000 - 75,000}{6,000} = \frac{450,000}{6,000} = 75,000 \text{ lbs.}$$

The strain on the Tension-rod = 75,000 lbs.

This completes the second Panel.



Let us now pass on to consider the strains for all the members in the last two Panels. From the foregoing formulas, page 8, we may obtain the moments of strains. Let Figure 3 represent the Truss loaded as shown.

Compressive strain in the Rafter between the points I and G = X_2 when the point of rotation is around H; from the equation we obtain

$$X_2 = \frac{W \cdot L_1 - (W_1 l_2)}{x_3}$$

Let $W = 21,000$ lbs.

$$L = 25 \text{ feet}$$

$$W_2 = 6,000 \text{ lbs.}$$

$l_2 = 12.5$ “

$$x_3 = 9.3 \text{ feet.}$$

$$X_2 = \frac{21,000 \times 25 - (6,000 \times 12.5)}{9.3} = \frac{525,000 - 75,000}{9.3} = \frac{450,000}{9.3} = 48,387 \text{ lbs.}$$

We have therefore the strains in the Rafter between the points I and G, 48,387 lbs.

Compressive strain on the Strut between the points I and H = Y_2 when the point of rotation is round A.

$$Y_2 = \frac{W_1 l_2}{x_2}$$

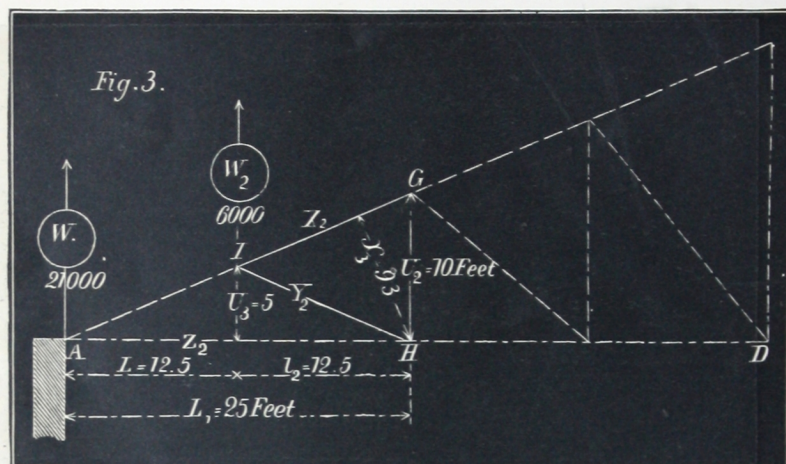
Let $W = 6,000$ lbs,

$$l_2 = 12.5 \text{ feet.}$$

$$x_2 = 9.3 \quad "$$

$$Y_2 = \frac{6,000 \times 12.5}{9.3} = \frac{75,000}{9.3} = 8,064 \text{ lbs.}$$

We have then for the strain on the Strut between the points I and H, 8,064 lbs.



Tensile strain on the Tension-rod between the points A and H = Z_2 when the point of rotation is round I.

$$Z_2 = \frac{W \cdot L}{U_3}$$

Let $W = 21,000$ lbs.

$L = 12.5$ feet.

$U_3 = 5.0$ "

$$Z_2 = \frac{21,000 \times 12.5}{5} = \frac{262,500}{5} = 52,500 \text{ lbs.}$$

We have then for the strains on the Tension-rod between the points A and H, 52,500 lbs.

The tensile strain produced on the Queen-rod between the points G and H = U_2 when the point of rotation is round A.

$$U_2 = \frac{W_1 l_2}{L_1}$$

Let $W_1 = 6,000$ lbs.

$l_2 = 12.5$ feet.

$L_1 = 25.0$ "

$$U_2 = \frac{6,000 \times 12.5}{25} = \frac{75,000}{25} = 3,000 \text{ lbs.}$$

The strain on the Queen-rod between the points G and H is 3,000 lbs.

The tensile strain on the Tension-rod between the points A and H = Z_2 when the point of rotation is round I.

$$Z_2 = \frac{W \cdot l_2}{U_3}$$

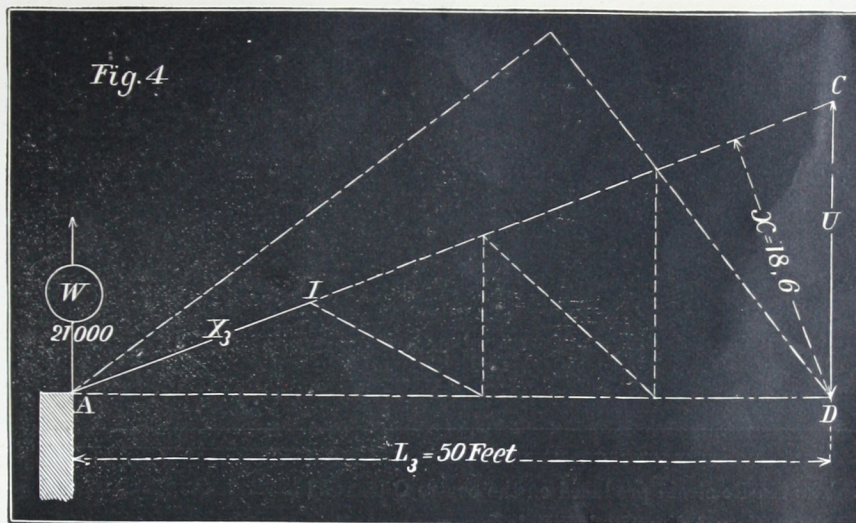
Let $W = 21,000$ lbs.

$l_2 = 12.5$ feet.

$U = 5.0$ "

$$Z_2 = \frac{21,000 \times 12.5}{5} = \frac{262,500}{5} = 52,500 \text{ lbs.}$$

The strain on the Tension-rod between the points A and H is 52,500 lbs.



Compressive strain on the Rafter between the points A and I = X_3 if we choose a convenient point for rotation in the line Z, per example D.

Fig. 4, as shown; the equation in this case will be

$$X_3 = \frac{W \cdot L_3}{x}$$

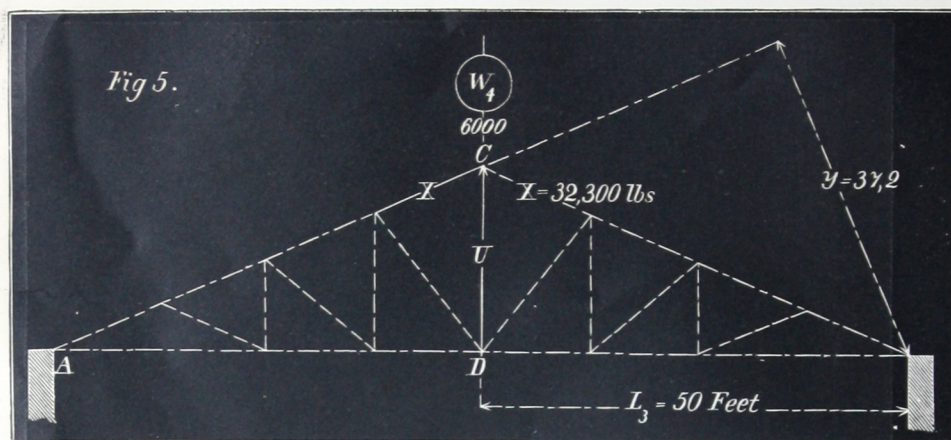
Let $W = 21,000 \text{ lbs.}$

$L = 50 \text{ feet.}$

$x = 18.6 \text{ feet.}$

$$X_3 = \frac{21,000 \times 50}{18.6} = \frac{1,050,000}{18.6} = 56,457 \text{ lbs.}$$

We have then for the strains in Rafter between the points **A** and **I**, 56,457 lbs.



The tensile strain produced on the centre Queen-rod between the points **D** and **G** = **U**; the only strain not directly deducible is **U**, we must therefore use the strain of the joining Rafter; the equation will be (see Fig. 5),

$$U = \frac{X y - (W_4 L_3)}{L_3}$$

Here, **X** = 32,300 lbs.

y = 37.2 feet.

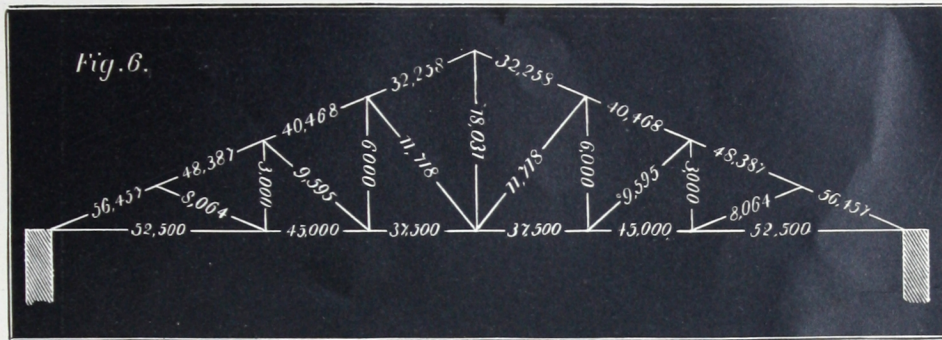
L₃ = 50 "

W = 600 lbs.

$$U = \frac{32,300 \times 37.2 - (6000 \times 50)}{50} = \frac{1,201,560 - 300,000}{50} = \frac{901,560}{50} = 18,031 \text{ lbs.}$$

The strain on the centre Queen-rod **U** is 18,031 lbs.

This completes all the strains.

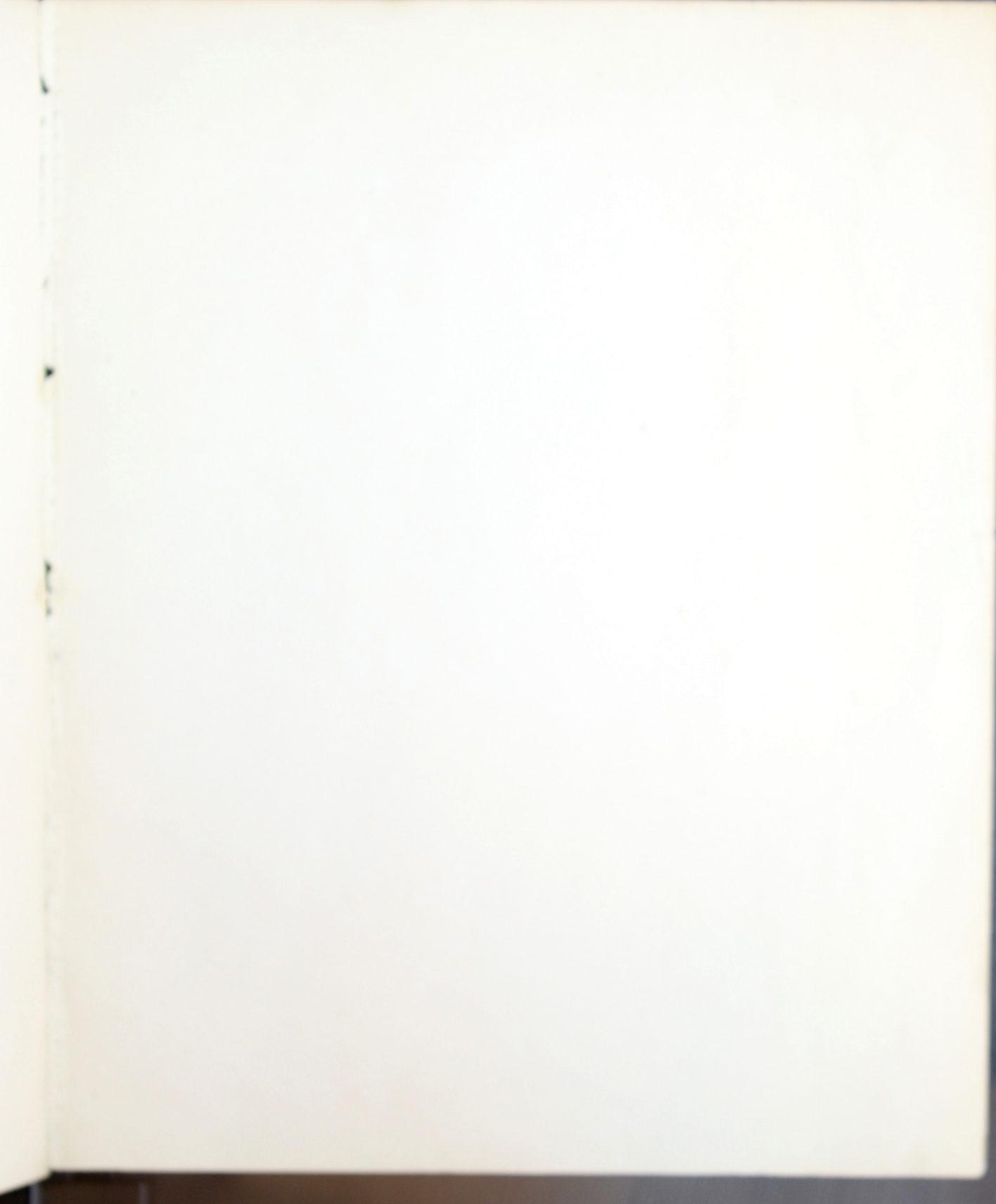


We have now concluded our remarks upon the construction of Iron Roofs; but think it desirable here to observe that the calculations given in the preceding pages with regard to the terminations of strains may with equal accuracy be applied to Timber Roofs. The Queen-rods should be of wrought iron: the strain produced in each member is shown by Diagram, Fig. 6.

The Tension and Queen-rods, being subject to tensile strains only, may be formed of round or rectangular sections; but rafters being subject to compressive strains, must be formed of **T** or **H** iron for the struts Tubes. **T** or **H** Beams may conveniently be adopted.







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Manufacturers and Builders of Gas Works, &c., of all Descriptions,
OF THE MOST APPROVED PLANS.

WROUGHT-IRON ROOF FRAMES,

For Slate or Corrugated Iron Coverings, with Cast-iron Cornice Gutter. Iron Doors and Frames, Wrought-iron Pivot Blinds, Windows and all kinds of Castings and Smith Work for Building.

BENCH CASTINGS,

Retorts and all castings and Wrought-Iron Work required for Setting them on the Latest Plan. Tar Gates, Stand Pipes, Retort Lids, Cotter Bars, Coal and Coke Wagons, and Stokers' Tools.

EXHAUSTERS.

Exhausters and Compensators, By-Passes to pass from 4,000 to 150,000 cubic feet of Gas per hour, with Engines, Governors, Pressure and Vacuum Gauges.

SCRUBBERS.

Single or Multitubular Scrubbers, with Self-Acting Pumps for Ammonia Water.

WASHERS.

Cataract and Single and Multitubular Spray Washers.

CONDENSERS.

Single and Multitubular Air and Water Condensers.

PURIFIERS,

For Purifying from 1,000 to 2,000,000 cubic feet capacity daily, with either wet or dry Lime or Oxide of Iron, and with either Ash Rivetted or Wrought or Cast-iron Lime Sieves.

CARRIAGES.

Movable Lifting Carriages for Purifiers, arranged either for Floor or Overhead use.

METERS.

Square and Round Meters of any capacity.

GAS-HOLDERS.

Single Lift and Telescopic Gas-Holders, with Cast or Wrought-iron Suspension Frames.

GAS-GOVERNORS.

Station Governors, with Regulating and Indicating Columns for Inlet and Outlet Pipes, also Dry Governors with Flexible Diaphragms for Underground Pipes.

STOP VALVES.

Double Faced Stop Valves for Gas or Water, from three inches to forty-eight inches Diameter. These Valves are proved on both sides, with a heavy Water Pressure, Flange and Bell Pipes, Fittings and Drips of all descriptions. Steam Boilers and Hot Water Apparatus for Heating Building, and Gas-Holder Tanks. Lamp Posts and Lanterns.